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Technical Report 975

Selection of Personnel for Stressful Occupations: The Potential Utility of Psychophysiological Measures as Selection Tools

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March 1993

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13. ABSTRACT (Maximum 200 words) The Manpower and Personnel Research Division identified a requirement to assess whether selection and classification for stressful occupations could be improved. An interdisciplinary review, evaluation, and synthesis was carried out to assess the feasibility of using psychophysiological measures to select individuals resistant to stress to improve selection and classification methods for stressful occupations. To integrate this literature, a new psychophysiological model was developed in the context of current industrial/organizational practice. Researchers concluded that psychophysiological measures do have the potential to improve the selection/classification standards for stressful occupations. Three recommendations were made for future research. First, experimentation should begin to assess the validity of the proposed psychophysiological measures to predict successful performance under stress. Second, since people who cope successfully appear to share some personality traits, research should be conducted into the personality correlates of successful task performance under stress. Third, occupations should be analyzed in terms of stress dimensions to provide a rationale for the identification of valid predictors and criteria of successful performance in stressful jobs. A demonstration study was outlined.				
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**A Field Operating Agency Under the Jurisdiction
of the Deputy Chief of Staff for Personnel**

EDGAR M. JOHNSON
Acting Director

Research accomplished under contract
for the Department of the Army

The Wellesley Hospital and the University of Toronto
San Francisco State University

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Technical Report 975

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The Potential Utility of Psychophysiological
Measures as Selection Tools**

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FOREWORD

U.S. Army activities such as Special Forces and Ranger training and missions involve a high degree of physical and mental stress. As a result, it may be effective to recruit and train soldiers who are resistant to the effects of physical and mental stress. This possibility was explored in a review of the research literature on psychophysiological and personality measures. This report presents the findings of that literature review.

The report reviews the concepts of stress and coping and the existing literature on the use of psychophysiological and personality measures to predict successful performance under stress. The researchers propose an alternative model for representing how effective performers deal with stress to minimize its impact on task performance. Based on this model, they recommend additional physiological processes to be measured in future research and various lines of inquiry that would serve to clarify unanswered issues.

This effort was part of the "Specialized-MOS Classification and Army-Wide Selection Methods" task conducted by University researchers through the U.S. Army Research Office and Battelle under the Selection and Classification Technical Area of the Manpower and Personnel Research Division.



EDGAR M. JOHNSON
Acting Director

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Finally, we are grateful to Edgar Johnson, Acting Director of ARI, for initiating the concept of employing psychophysiological measures as selection/classification tools.

SELECTION OF PERSONNEL FOR STRESSFUL OCCUPATIONS: THE POTENTIAL UTILITY OF PSYCHOPHYSIOLOGICAL MEASURES AS SELECTION TOOLS

EXECUTIVE SUMMARY

Requirement:

Since stress can have negative effects on performance and the U.S. Army is composed of a number of occupations that are inherently stressful, it is important to discover whether the selection and classification of personnel for stressful occupations can be improved. Based on this need, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) identified a requirement to conduct an interdisciplinary review, evaluation, and synthesis of the feasibility of using psychophysiological measures to improve the selection and classification of personnel for stressful occupations. This report examines the potential for using psychophysiological measures as predictors of successful performance under stress to improve selection and classification methods.

Procedure:

The report begins by identifying the need for better selection of personnel for stressful occupations. Following these introductory remarks, the effects of stress on performance are reviewed and an examination of the theoretical remarks, the effects of stress on performance are reviewed and an examination of the theoretical underpinnings associated with stress and coping is presented. Based on this review, the authors conclude that stress is best characterized as the dynamic relationship between situational demands, the cognitive appraisal of those demands, and an individual's response to those demands. Effective coping occurs when there is a balance between environmental demands and an individual's perceived available resources. The report then reviews the literature on stressful occupations, with a special emphasis on those occupations relevant to the military. Especially critical are studies that explored the utility of psychophysiological measures to differentiate successful from less successful individuals in stressful situations. Specifically, the following occupations are reviewed: Law enforcement, underwater divers, soldiers, bomb disposal technicians, and parachutists. While this literature provided useful information, an integration was needed. To accomplish this integration, a new psychophysiological model is proposed to provide a theoretical explanation of the findings. Finally, all of this information is framed in the context of current industrial/organizational practice.

Findings:

Personnel who perform effectively under stress appear to share several characteristics. In terms of psychophysiological characteristics, people who cope successfully tend to show lower heart rates and reduced heart rate variability during periods of high stress. In terms of personality characteristics, those personnel who cope successfully with stress tend to show lower anxiety and fear in dangerous situations, are introverted, well-adjusted, and self-confident, prefer to work alone on practical problems, and are more stable and less impulsive than those who cope less effectively with stress. A new

psychophysiological model was developed to explain these reported findings. It was proposed that when personnel are faced with potentially threatening or dangerous environments but optimal performance is required, successful copers engage a task-oriented coping process and actively suppress or inhibit arousal normally caused by exogenous (environmental) and endogenous (fear or anxiety) stimuli. It was concluded that heart rate and heart rate variability measures are potentially sensitive discriminators (and perhaps predictors) of successful performance in stressful occupations and should be explored further. In addition, these proposed psychophysiological measures appeared to be feasible for use in experimental and practical settings. As a caveat to these conclusions, however, it was recognized that the predictive validity of these psychophysiological measures has yet to be established and that it is critical to examine heart rate and heart rate variability changes during stress and relate these changes to the level of performance.

Utilization of Findings:

Researchers recommend that three parallel areas of study be undertaken to validate the proposals in this report. First, experimentation should begin to assess the proposed psychophysiological model designed to explain individual differences in successful coping under stress. While the proposed psychophysiological measures and the model show promise, their validity must be empirically verified before these measures can be employed to select individuals for stressful occupations. Initially, experiments should be conducted in the laboratory where there is better control over independent (stress-related) and dependent (psychophysiological) variables. However, if these initial laboratory experiments are successful, more operational (real or training) settings should be investigated. Second, since successful copers appear to share a cluster of personality traits, research should be conducted into the personality correlates of successful task performance under stress. Third, occupations should be analyzed in terms of their stress dimensions. This analysis would provide a rationale for the identification of valid predictors and criteria of successful performance in stressful jobs. A demonstration experiment is outlined as an initial step in this research process.

SELECTION OF PERSONNEL FOR STRESSFUL OCCUPATIONS: THE POTENTIAL UTILITY OF PSYCHOPHYSIOLOGICAL MEASURES AS SELECTION TOOLS

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SELECTION OF PERSONNEL FOR STRESSFUL OCCUPATIONS: THE POTENTIAL UTILITY OF PSYCHOPHYSIOLOGICAL MEASURES AS SELECTION TOOLS

INTRODUCTION

Among aviators one often hears the adage that flying can be characterized as "hours and hours of total boredom punctuated by moments of sheer terror." To varying degrees this characterization of acute stress in a specific occupation is applicable to many civilian (e.g., nuclear power operators, air-traffic controllers) and military (e.g., Special Forces, Rangers, Airborne personnel, helicopter and fighter pilots, bomb disposal experts, emergency personnel) occupations. In many military occupations, task performance may involve only limited or minimal encounters with stress situations. However, other occupations, such as those in Special Forces, Ranger, and Airborne Emergency units, have greater potential to experience acute stress conditions. What is unique to military occupations is that **all occupations** have the potential for a marked elevation in stress if routine task performance must be carried out under combat conditions. For military planners, recruiters, trainers, logicians, commanders, and servicemen, at least three critical questions arise from a consideration of the stressful nature of military occupations: (1) how does stress affect job performance, (2) what occupations have greater potential to experience quantitatively or qualitatively greater stress (i.e., how do occupations align themselves on stress dimensions), and (3) can negative consequences of occupational stress be reduced within military occupations by selecting individuals more capable of operating effectively under stress. While there is considerable research and some consensus on the first question, there is little knowledge or consensus regarding the latter two questions.

The purpose of the present report is to address all three questions in the opening paragraph, though the emphasis will be placed on the final question. With respect to this final question concerning selection, this report is specifically intended to examine the viability and

feasibility of employing psychophysiological measures of individual differences to more accurately select and classify individuals for occupations where performance under demanding, stressful, and threatening conditions is critical. To satisfy this goal, the literature relevant to using psychophysiological measures as selection/classification criteria was reviewed and deficiencies in current industrial/organizational approaches to job selection/classification for stressful jobs were examined. A psychophysiological model was developed to explain and integrate the existing literature and to provide a framework for future investigations. Current industrial/organizational approaches to occupational stress were also reviewed. Finally, three parallel research lines with respect to the selection of personnel for stressful occupations were proposed.

RATIONALE FOR ALTERNATIVE SELECTION/ CLASSIFICATION CRITERIA

The problem of selecting military personnel for specialized high-stress assignments presents a major challenge. For some occupations, it remains difficult to discriminate among a group of individuals who have similar high levels of knowledge, skills, and abilities (KSAs). For example, in highly stressful jobs, KSAs alone will not discriminate those who will perform well from those who will not. Consequently, Hogan and Hogan (1989) have recommended that other predictors be investigated when people are screened using cognitive skills tests (i.e., the Armed Services Vocational Aptitude Battery (ASVAB)) and low performance or high attrition persists.

This report examines the potential utility of psychophysiological measures to increase the predictive accuracy of performing well under stressful conditions. The studies cited in this report clearly support the assertion that stress can have a negative impact on performance through a wide range of possible mechanisms. The primary emphasis and intent of this paper is to examine whether psychophysiological measures can be useful in selecting and classifying applicants who will be more resistant and less vulnerable to the effects of stress. From a

practical viewpoint, the question is "do psychophysiological measures offer an incrementally useful tool to predict which individuals will respond with superior performance under stressful conditions?" Prior to discussing the literature relevant to successful coping with stress in various occupations, the relationships between stress, coping and performance are briefly reviewed. This review is intended: a) to support the assertion that stress impairs performance, and b) to provide a theoretical context in which to understand the concepts of stress and coping.

STRESS, COPING, AND PERFORMANCE

Stress and Performance

Overall, there is overwhelming support for the conclusion that stress has negative consequences for performance. Performance has been shown to be impaired by a variety of stressors such as high noise (Broadbent, 1978; Poulton, 1978), increased workload (Goldstein & Dorfman, 1978), crowding (Hayduk, 1983; Schmidt & Keating, 1979), performance pressure (Baumeister, 1984; Baumeister & Steinhilber, 1984), psychological stress (Berkun, 1964), and anticipatory threat of shock (Wachtel, 1968). In operational performance studies, Villoldo and Tarno (1984) have reported that performance stress alone can cause increased errors while Idzikowski and Baddeley (1983) have reported that the time taken to complete manual tasks will double under conditions of high stress. Performance impairment has also been demonstrated in more dramatic operational settings where individuals have been exposed to dangerous situations such as parachuting (Fenz & Epstein, 1967, 1968; Fenz & Jones, 1972a, 1972b; Hammerton & Tickner, 1969), simulated chemical warfare conditions (Brooks, Ebner, Xenakis, & Balson, 1983; Carter & Cammermeyer, 1985), and bomb disposal (Cox, Hallam, O'Connor, & Rachman, 1983; Rachman, 1983a, 1983b, 1990).

Although these cited studies clearly demonstrate that different types of stress can impair performance in different ways, the studies do not provide a common definition of

stress. The following sections are intended: a) to review and define stress, and b) to provide a theoretical context in which to understand stress and coping. These sections lay the foundation for the later analysis of whether psychophysiological measures can be used as selection and classification tools to assign specific individuals to stressful occupations.

Definitions of Stress

Historically, stress has been conceptualized in psychology in three ways. The first and earliest approach was to conceptualize stress in a way that paralleled its usage in mechanical engineering, i.e., stress produces strain which leads to structural damage. From this point of view stress was defined with respect to the stimulus properties of the situation or event (Appley & Trumbull, 1986). Consistent with a strong behaviorist tradition, this view of stress assumed that stress was equivalent to the load placed on a person and the amount of stress would be related to, and could be defined by, objective and quantifiable stimulus characteristics. Also consistent with the engineering analogy was the assumption that a specific amount of stress would result in a specifiable amount of strain on the person and that this strain would predict psychological or physiological breakdown.

A second approach has been to conceptualize stress in terms of response characteristics. Perhaps the strongest advocate of this approach was Hans Selye (1976). He defined stress as a generalized nonspecific physiological response to a diverse array of noxious stimuli which is characterized by changes in the pituitary-adrenal system. Selye (1976) described the process of coping with stress in terms of a three-stage model called the General Adaptation Syndrome. In the first stage of coping the individual reacts or responds to the stressful stimulus (alarm reaction). With the continued presence of the stressor, the individual will adapt to the stressful environment (adaptation or resistance stage). However, if the stressor persists for prolonged periods, the individual moves into a stage of exhaustion where resistance is lost and multisystem breakdown occurs.

In more recent times, a third approach has received wider acceptance. Although there are many variants, this final approach has been labeled transactional, interactional, or cognitive-relational: stress is defined in terms of a specific relationship between the individual and the environment. Perhaps the most detailed theory based on this approach to stress is the cognitive-relational theory of Lazarus & Folkman (1984) (see also, Cox, 1978; Lazarus, 1966, 1968; Lazarus & Launier, 1978) which defines stress as an imbalance between the perceived demands of the situation and the perceived resources necessary for successful coping with the situation. Central to this approach is the notion of cognitive appraisal or cognitive evaluation. Rather than defining stress in terms of either objective stimulus characteristics or objective physiological responses, the cognitive-relational theory concentrates on the mediational evaluative process carried out by the individual based on the perceived relationship between demands and resources (Fleming, Baum, & Singer, 1984). Thus, reciprocal causality between individual, situational, and response variables is assumed.

Another assumption of the cognitive-relational approach is that the mediational or evaluative process is dynamic. At any moment in a given situation or environment, the individual must appraise the environmental demands, assess the availability of the resources applicable to those demands, and then respond. In other words, there is a dynamic and constantly changing appraisal of the situation. Based on this view, individual difference variables become important since factors that affect appraisal can influence one's ability to cope effectively with the environmental demands. For instance, there has been a growing interest in assessing the relationship between different emotional categories (e.g., fear, happiness) and the resulting differential appraisal of the environment (Arnold, 1960; Frijda, 1987, 1988; Frijda, Kuipers, & ter Schure, 1989; Lazarus, 1968; Scherer, 1984; Smith, 1989; Smith & Ellsworth, 1985; 1987; Tesser, 1990).

Stress and Coping

Given that stress is best characterized as the dynamic relationship between situational demands, the cognitive appraisal of those demands, and one's response to those demands, coping under stress requires the appropriate cognitive appraisal of the environmental demands. Effective coping occurs when there is a balance between environmental demands and available resources. For example, those individuals who will successfully cope with a "stressful" situation will be those individuals who will appraise, or reframe, the situation to be within their ability to apply existing resources to the task at hand. From this perspective, the selection and classification goal for "stressful" occupations is to place individuals who appraise "high stress" conditions as being within their abilities in high stress occupations.

There may be a number of conceivable ways to influence the appraisal by the individual, and thus induce successful coping in natural settings. Two general approaches can be easily conceived: one centering on "state" variables and the other centering on "trait" variables. The approach that focuses on state variables has been largely divided into broadly defined types of situations requiring different coping skills. This approach focuses on defining situations in terms of the type of coping skills required, and then developing behavioral strategies designed to provide individuals with skills that allow them to cope with specific types of situations. For instance, Folkman & Lazarus (1980) have identified two broad categories of problem-focused and emotion-focused situations for which different coping strategies can be developed. On the other hand, Moos and Billings (1982) have identified nine subtypes of coping within three major coping categories, and, in a later refinement, these authors (Billings & Moos, 1984) developed a scale to measure the presence of five principal coping strategies.

However, there are various limitations with this approach. For example, many situations do not clearly fall into one category or another which perhaps reflects the inherent multidimensionality of stress and coping. It is likely that any real or natural situation is multidimensional at any point in time, especially if the situation is considered dynamic. This

approach also assumes that appraisal of the situation is entirely cognitive. Even in the unlikely event that appraisal is entirely cognitive, this approach further assumes that the appraisal will be sufficiently accurate to elicit an appropriate behavioral strategy. This assumption is also not likely to be valid under natural conditions.

The alternative "trait" approach is to select those individuals with relatively permanent characteristics which make them less vulnerable to the effects of stress. Previous studies have sought to uncover characteristics of coping that could be characterized as relatively stable and enduring. For instance, Epstein and Meier (1989) have considered constructive thinking as a global coping style that might be related to major nonintellectual components of adaptation. Others have examined other personality characteristics, such as monitoring/blunting (Miller, 1980, 1987), high/low ego strength (Roesler, 1973), and repression/sensitization (Byrne, 1964), as relatively stable coping styles. However, these personality trait approaches have been criticized because they fail to capture the complexity of coping situation and frequently have not been highly predictive with respect to identifying successful copers in specific situations (Lazarus & Launier, 1978; Lazarus & Folkman, 1984; Folkman & Lazarus, 1985). Furthermore, none of these trait approaches have attempted to examine the underlying psychophysiological correlates of individuals who more successfully engage in, and cope with, stress.

While neither state nor trait approaches have demonstrated substantial predictive validity, this literature suggests that individuals who perform successfully in stressful occupations have common characteristics that differentiate them from those who do not. It has been demonstrated that certain inherent characteristics (e.g., locus of control, socialization, sensation-seeking) enable effective copers to appraise high stress conditions as being within their abilities. Thus, this literature suggests that the appraisal of stressful situations is moderated by inherent personality traits. A better understanding of the complex interrelationship between the individual and environmental demands should improve the predictive validity of personality characteristics. Our understanding of these dynamic

processes would be improved by a more clear and objective assessment of individual reactivity to the environment through psychophysiological techniques.

PREDICTING PERFORMANCE IN STRESSFUL OCCUPATIONS

Given that stress can adversely affect performance, it is important to differentiate individuals who effectively cope with stress from those who do not. However, the experimental literature on performance during stress in occupations that have military relevance is scant. This literature comes from only a few occupations and primarily addresses personality traits, although a few studies have examined psychophysiological, physical, and cognitive constructs. Furthermore, the literature is correlational in nature, and concurrent validation is the only method that has been used to validate *predictors of performance during stress*. Nevertheless, some consistencies have emerged, and these findings will provide the foundation for a model of predicting successful performance.

Law Enforcement

The literature on selection procedures for law enforcement personnel was surveyed, and, overall, this literature revealed that selection procedures primarily endorse exclusionary criteria. Applicants are screened out for obvious physical, psychological, and intellectual deficiencies and the best of the remaining candidates are selected based on recruitment needs. Law enforcement agencies have generally employed various psychological screening tools in attempts to predict the emotional stability of future officers under stress. Largely spurred by the Presidential Commission on Law Enforcement (1967) to improve the emotional fitness screening of police recruits, many states began implementing psychological evaluations at the selection level so that by 1975, 42 states had some form of psychological screening (Goldstein, 1975). By 1985 psychological screening of police and correctional officers was made mandatory in California and 10 other states immediately followed suit (Behrens, 1985).

Despite the need and emphasis to select law enforcement officers who will be able to operate under stress, most of the selection and classification techniques have employed standardized psychological tests. Most often, the Minnesota Multiphasic Personality Inventory (MMPI) and California Psychological Inventory (CPI) have been employed (cf. Hargrave & Berner, 1984) and many consider the MMPI (e.g., Beutler, 1985) and the CPI (Fabricatore, Azen, Schoentgoen, & Snibbe, 1978; Hogan & Kurtines, 1975) valid tools for the selection of officers. More recently the Inwald Personality Inventory (Inwald, Knadz, & Shusman, 1983) has been developed and others have reported that this new inventory is valid (Ostrov & Cavanaugh, 1986). In most of these reports, however, the validity of these psychological tests should be characterized as face validity rather than predictive validity as rigorous experimentation and assessment is generally lacking.

However, as researchers in this area have become more sophisticated, they have noted that outcome measures of success have been poorly defined and more often reflect non-job related factors such as friendship patterns (Poland, 1984). Ostrov (1986) has also noted that restriction of range problems limit the predictive power of these instruments. Based on these problems, some have argued that many of these personality predictors of success in law enforcement should not be considered useful. For instance, with respect to the most common tool used for selection, the MMPI, Mills and Stratton (1982) concluded that "there is no evidence to support the MMPI as a predictor of police performance." Ostrov (1986) similarly concluded that there was little empirical support for the MMPI. This view has led some to develop "situational stress tests" (Mills, 1976; Pugh, 1985) to assess reactivity to specific stress events. However, police selection has not employed psychophysiological techniques in their selection and classification procedures (outside of polygraphic "lie detection" assessment which is mistakenly aimed at assessing the character of the individual (Furedy & Heslegrave, 1991)).

Underwater Divers

The majority of the research conducted with divers has involved personality measures. Knapp, Capel, and Youngblood (1976) measured free-floating anxiety of professional divers before, during, and after a dive, and compared the divers' responses to normative data. They found that anxiety levels for the professional divers prior to and during the dive were lower than those of the normative group, but did not differ after the dive (e.g., the professional divers' anxiety increased, or recovered, after the dive).

Biersner and LaRocco (1983) used personality measures to assess sensation-seeking, locus of control, socialization, and trait anxiety of Navy divers. The divers completed the personality measures and these results were compared to those of a normative group from the general population (an experimental condition was absent in this study). Biersner and LaRocco (1983) found that, compared to the normative group, Navy divers reported (1) higher internal locus of control, (2) fewer and less friendly social interactions with others, and (3) lower levels of chronic or trait anxiety. The scores for the five subscales of the sensation-seeking measure produced a mixed pattern of significant results: the divers were significantly higher on the thrill- and adventure-seeking subscale, but they were significantly lower on the experience seeking and disinhibition subscales than the normative group.

Finally, Hogan and Hogan (1989) included tests of cognitive abilities, vocational interests, and physical ability along with personality measures as predictors of performance in explosive ordnance training and job performance. Although they found that the cognitive abilities tests did not predict the performance outcome, a regression equation including vocational interest, physical ability, and personality traits did. The realistic interests subscale of the vocational interest test, the nine subscales of the personality test (ranging from science ability to impulse control), and the seven physical performance tests (ranging from lift strength to dynamic flexibility) were combined to form a prediction equation. Specifically, they found that this test battery predicted diving success ($R=.51$), course success ($R=.47$), and diving status ($R=.61$). Hogan and Hogan (1989) have concluded that successful trainees and divers

have practical interests, are introverted, well-adjusted, self-confident, adventuresome, prefer to work on practical problems, prefer to work alone, and physically they have attributes such as physical strength and dynamic flexibility.

Soldiers

In a somewhat older study of soldiers who experienced significant war-stress and injury, Merbaum and Hefez (1976) have discussed those aspects of personality and psychopathology that might lead to breakdown under war-time stress. They attempted to discover whether the stress of war induced a differential clinical portrait for soldiers who became psychiatric casualties compared to those who remained as medical casualties following exposure to stress. *Their subjects were Israeli and American soldiers injured in the Yom Kippur and Vietnam Wars. None of the subjects had a distinctive premorbid history in terms of psychiatric illness and all soldiers were assessed as part of their hospitalization immediately (within 1-2 weeks) following their injury. (The data from the American soldiers was reported by Lumry, Cedarleaf, Wright, and Braatz (1972).)*

Merbaum and Hefez (1976) found that both Israeli and American psychiatric casualties were elevated on their MMPI scores for Schizophrenia, Depression and Psychoasthenia. American psychiatric casualties were also elevated in Psychopath Deviate and Hypomania scores, whereas Israeli psychiatric casualties were elevated in Hypochondriasis scores. The authors concluded that Israeli psychiatric casualties were significantly higher on scales indicating the presence of painful emotional distress, whereas the American psychiatric casualties showed aspects more consistent with personality disorders associated with impulsivity, aggression, and poorly controlled behavior. The authors also found that among the American non-psychiatric, medical casualties, scales indicating generalized instability, anxiety, and impulsivity seem to be higher than for Israeli non-psychiatric casualties. Based on these results, a cultural difference toward breakdown under stress may be evident, with instability and poor control of impulsiveness being better predictors of breakdown under

stress for American soldiers. It is unknown, however, how these variables actually relate to poor performance under stress.

Keinan (1988) recently investigated training for dangerous task performance because, as he noted, "a coherent, well-grounded body of knowledge concerning the training of individuals to cope with threats to their physical integrity has yet to be developed" (pp. 355-356). To measure performance and stress reactions, Keinan used the Confidence Expectation Questionnaire (CEQ), which was developed in 1986 (Keinan, 1986), to divide subjects on a personality variable reflecting their expectation of being injured; he then manipulated training fidelity (realistic vs. unrealistic training) and performance feedback (positive vs. negative). Performance was measured as hits on two targets during participation in the Trench Test (a simulated trench), and stress was measured using the Stress Self-Report Scale. He found that the fidelity training moderated the results of the CEQ and performance feedback. Specifically, individuals who reported low confidence on the CEQ (i.e., did not expect to be injured during dangerous training) benefited more from realistic training; they performed better and reported lower stress than the other subjects. In addition, subjects who received positive feedback and realistic training performed better and reported lower stress than the other subjects. These data suggest that if individuals view themselves as likely to be successful in the task environment (low probability of injury and high probability of successful task completion), they are more likely to exhibit successful performance and will benefit from more realistic, higher-fidelity training regimens. While these results may be useful in uncovering factors related to skilled motor performance, they do not necessarily apply to tasks that are primarily cognitive in nature.

Bomb Disposal Operators

Somewhat more attention has been paid to the assessment of cognitive skills, personality constructs, and psychophysiological indices for predicting responses to stressful conditions in bomb disposal operators. These studies have attempted to identify the

differences between operators with varying levels of success. Cooper (1982) examined 40 bomb disposal operators in Northern Ireland using the 16PF Inventory (Cattell, Eber, & Tatsuoka, 1970), Clinical Analysis Questionnaire (Delhees & Cattell, 1971), and the Dynamic Personality Inventory (Grygier, 1970). He identified 20 successful bomb disposal technicians as those who had high ratings on quality of work under stress, successfully completed complex and dangerous assignments, completed large numbers of incidents during intense bomb activity, and completed their full tour of duty. Less successful operators were defined as those who did not meet all of the above criteria. Cooper (1982) found that there were no differences between highly successful and less successful bomb disposal operators on personality traits (16PF) or pathological (Clinical Analysis Questionnaire) variables, but the two groups differed in terms of their interpersonal/social behavior (Dynamic Personality Inventory). Highly successful bomb disposal operators had lower levels of affiliation and affection motivation, had difficulty in forming and maintaining close personal relationships, and had a tendency toward non-conformity with less reliance on conventional values and judgments. In other words, they tended to be social isolates, preferred to work alone (maintain psychological and social distance), preferred to work with things, not people, and were less susceptible to conformity and conventional responses (which may lead to greater flexibility). Cooper (1982) suggested that such characteristics may benefit individuals faced with a high stress environment and critical task performance because these individuals are less distractible and more flexible in their approach to a problem.

In several studies, Rachman and his colleagues examined subjective, behavioral, and psychophysiological predictors of performance in bomb disposal operators. In 1983, Cox, O'Connor, and Rachman measured subjective (e.g., self-reported anxiety), behavioral (e.g., performance), and psychophysiological (e.g., heart rate) reactions of a group of seven bomb disposal operators during a psychomotor conflict task and compared these results with seven non-decorated bomb disposal operators of equivalent experience. While there were no differences in terms of subjective or performance reactivity, decorated operators maintained a

lower cardiac rate during difficult discriminations under threat of shock. These data led Cox et al. (1983) to speculate that there was a distinctive pattern of cardiac reactivity among successful bomb disposal operators.

In a subsequent study, O'Connor, Hallam, and Rachman (1985) again examined subjective, behavioral, and psychophysiological predictors of performance of decorated, non-decorated, and less experienced bomb disposal technicians. Prior to entering the experiment, eight subjects in each of the three groups completed a Bodily Sensation Questionnaire (Borkovec, 1976), a Mood Adjective Checklist, and Thayer's (1971 a, b) Activation Checklist. In their laboratory experiment, they manipulated stress by administering electric shock during an auditory discrimination task. No differences existed in terms of performance. In terms of subjective responses, O'Connor et al. (1985) found that: (a) all groups showed a decrease in self-reported anxiety following the test, and (b) the decorated group reported higher anxiety on the morning before the experimental test session.

In terms of cardiac responses, the authors reported that: (a) decorated operators showed lower heart rate (HR) than the other two groups, (b) during the most difficult discrimination condition there were significant differences between all 3 groups with the decorated group showing lower HR (78 beats per minute (bpm)) than the non-decorated group (87.33 bpm) and the less experienced group (91 bpm), and (c) there were no significant differences between groups in HR variability (defined as the standard deviation from their mean HR). These data suggest that a lower HR response pattern may be a psychophysiological marker characteristic of successful coping.

In a further examination of decorated and non-decorated bomb disposal technicians, Rachman (1991) examined subjective and psychophysiological predictors of performance. He manipulated stress using electric shock administered during an auditory discrimination task; performance on the task could not be assessed because the task was designed to become increasingly impossible (i.e., under the most difficult conditions, the "discriminant" stimuli

were identical frequencies of 600 Hz). In terms of subjective data, Rachman (1991) found that during the three most difficult phases of the stress test, decorated technicians exhibited lower self-reported anxiety than the non-decorated technicians. Again, self-reported bodily sensations did not differ significantly between the two groups. In terms of physiological responses, although HR was consistently lower under all task conditions for the decorated group than for the non-decorated group, the difference was not statistically significant. (A further analysis of the data conducted by the authors of the present report showed that HR was significantly lower ($p=.05$) while listening to tones and during the third, shock-avoidance, discrimination trial). Further, although HR variability was not analyzed in the report, a re-analysis found that HR variability was markedly smaller (by about 50% during the first trial) in decorated operators. During the stress test, HR variability also showed a progressive reduction as the discriminations became more difficult, and this was especially evident for the decorated operators.

Rachman (1991) conducted a further discriminant analysis in order to identify the linear combinations of the measures that best discriminated decorated from non-decorated technicians. Only the first discriminant function significantly discriminated between the decorated and non-decorated groups, but no specific variable appeared to be more heavily favored than the others. Using a cutoff point mid-way between the group centroids, 100% of the technicians were correctly classified. All other discriminant functions were nonsignificant.

In the final set of analyses, Rachman (1991) attempted to discriminate decorated from non-decorated technicians using superior officers' subjective ratings of technician anxiety as well as the Attributional Style Questionnaire (ASQ). Specifically, Rachman (1991) gathered superior officers' ratings on the amount of anxiety displayed while dealing with an explosive device, peak anxiety during such an operation, amount of anxiety displayed between bomb disposal tasks, and the anxiety displayed during the entire period of the tour. The ASQ is designed to assess the technicians explanatory style by assessing their causal attribution with respect to accounting for important events. One hypothesis was that those individuals with a

more optimistic explanatory style (as measured by the ASQ) would show more courageous behavior (as measured by superior officers' ratings) than those with a more pessimistic explanatory style. Another hypothesis was that individuals who reported lower anxiety would show more courageous behavior than those who reported higher anxiety. Unfortunately, none of these predictions were supported in this relatively small group of bomb disposal technicians.

In summary, these studies suggest that a lower HR response pattern may be a psychophysiological marker characteristic of successful coping. This interpretation is consistent with other findings from the psychophysiological literature. For instance, it has been consistently reported that more successful coping with predictable stressful events, like shock, leads to HR decelerative responses (e.g., Lacey, 1967; Lacey & Lacey, 1974) while failure to cope with stress successfully (e.g., failure to learn shock-avoidance successfully) leads to HR acceleration (e.g., Brener, Phillips, & Conally, 1980).

Parachutists

Although the studies conducted on parachutists were not limited to military personnel alone, the results are relevant to assessing psychophysiological predictors of performance. In one study, Fenz (1964) found that the galvanic skin response (GSR) increased in response to parachute-relevant words with increased temporal proximity to a jump. In a later study, Fenz and Epstein (1968) used experienced and novice parachutists as predictors and reaction time during a word association test as a criterion. They found that in response to high jump-relevant words, novice jumpers produced an increase in GSR on the control day and the jump day. On the other hand, experienced jumpers produced an increase in GSR on the control day to highly relevant words, but a decrease in GSR on jump day. Experienced jumpers also demonstrated faster reaction times than novice jumpers to highly relevant words.

In a study examining the actual experience of parachutists, Epstein and Fenz (1965) had 33 experienced and inexperienced parachutists rate their fear and feelings of avoidance

(which they interpreted as measures of anxiety) at 14 points prior to their "jump."

Inexperienced parachutists showed a continuous rise in anxiety until the point of the jump; thereafter anxiety declined. Experienced parachutists, on the other hand, peaked in anxiety on the morning of the jump; thereafter anxiety fell until the point of the jump and then increased on landing.

Fenz and Epstein (1967) repeated the same procedure as Epstein and Fenz (1965) but included physiological response patterns by measuring heart rate (HR), respiration rate (RR), and skin conductance (often referred to as the galvanic skin response). For inexperienced parachutists, the physiological response pattern resembled that of the fear ratings in the Epstein and Fenz (1965) study with a steady increase in physiological arousal and fear until the point immediately preceding the jump. On the other hand, experienced parachutists showed lower values on all measures throughout the course of the jump. Moreover, physiological and psychological measures were dissociated during the course of the jump for experienced parachutists. For experienced parachutists, fear ratings peaked early in the course of the jump and the peak psychological reactions preceded peak physiological reactions. In other words, maximum fear ratings were accompanied by low physiological arousal rather than high physiological arousal.

Fenz and Jones (1972a) replicated and extended the work of Fenz and Epstein (1967) and included measures of RR, HR, and performance ratings. They found that novice parachutists showed an increase in RR and HR at the time of the jump, while experienced parachutists showed an increase well before the jump, then a decrease at the time of the jump. For novice parachutists, good performers showed an increase prior to the jump then a decrease at the time of the jump, while poor performers showed an increase at the time of the jump. For experienced parachutists, good performers showed an increase then a decrease at the time of the jump, while poor performers showed an increase at the time of the jump. Fenz and Jones (1972a) concluded that the most adaptive response (for both novice and experienced parachutists) is an increase in arousal early in the jump followed by a sharp

decrease, so that at jump time, arousal is at normal levels. Furthermore, Fenz and Jones (1972a) noted that the most capable and experienced parachutists are those who quickly produce laboratory-induced conditioned cardiac responses.

In a separate study, Fenz and Jones (1972b) found that when an element of uncertainty was introduced into an experienced parachutist's jump, physiological responses became similar to those of the novices. Furthermore, they reported that the physiological response made by experienced parachutists on jumps immediately following a parachute accident was the same as those who were inexperienced.

Other studies have also provided some empirical support for the conclusions of Fenz and his colleagues that experienced parachutists show lower HR responses, especially at critical times in the jump sequence, than novice parachutists. For instance, Deroanne, Cession, Juchmes, Servias, and Petit (1975) found similarities between the HR responses of novice and experienced parachutists except during parachute deployment and landing where experienced parachutists had lower heart rate compared to novices. Reid, Doerr, Doshier, and Ellerson (1971) reported similar results where over nine different points in time, novice parachutists had higher heart rates than experienced parachutists.

A comprehensive study of the differences between novice and experienced parachutists was conducted by Ursin, Baade, and Levine (1978). They examined the differences between novice and experienced parachutists along psychological (e.g., use of defense mechanisms), biochemical (e.g., cortisol, catecholamine, growth hormone), and psychophysiological (e.g., HR, blood pressure) dimensions. They concluded that different coping processes led experienced and inexperienced parachutists to differentially assess the adversity of the task. Those parachutists (mostly novice) who viewed the situation as uncertain and dangerous showed high psychophysiological arousal whereas those parachutists (mainly experienced) with greater confidence in their ability to handle the situation evaluated the situation as more safe and showed reduced psychophysiological and psychological reactions. Moreover, as

some novice individuals gained experience and began to increase their confidence in task performance, their psychophysiological responsiveness diminished.

Most recently, Schedlowski and Tewes (1992) assessed the psychophysiological responses and the self-reported arousal of experienced and novice sport parachutists before and during a parachute jump. They recorded HR and RR with a portable data recording system, and anxiety was assessed with a single-item rating scale. These measures were recorded at 12 points during the study, covering the times before the jump, during the jump, and after the jump. Schedlowski and Tewes (1992) found that novice parachutists expressed a higher degree of self-reported arousal during the jump sequence. Although the curves of the HR values for the two groups were almost parallel on the day of the jump, the novice jumpers displayed significantly higher HR than the experienced jumpers throughout the sequence as indicated by a significant difference between groups but no group by time sequence interaction. The lower HR for experienced parachutists was especially noticeable at the point of boarding the plane and at the point just before parachute deployment. Statistically significant differences in RR between the two groups were absent in this study, but at the point of parachute deployment the experienced parachutists showed a marked reduction in RR.

Schedlowski and Tewes (1992) suggested that their results disconfirm the inhibitory anxiety reaction hypothesis developed by Fenz and Epstein (1968). Instead, they suggested that their results support the assumption of Ursin and his colleagues (1978) that different coping processes for experienced and novice jumpers (due to differences in experience levels) lead them to assess the adverse situation differently.

Summary

Overall, the literature on predicting successful performance under stress suggests that personnel who perform effectively under stress share several characteristics. In terms of personality characteristics, they tend to: (a) show lower anxiety (Biersner and LaRocco, 1983;

Knapp et al., 1976; Rachman, 1991) and fear (Epstein and Fenz, 1965) during dangerous situations, (b) score higher on internal locus of control and thrill- and adventure-seeking, and have fewer and less friendly social interactions with others (Biersner and LaRocco, 1983), (c) be introverted, well-adjusted, self-confident, adventuresome, prefer to work on practical problems (Hogan & Hogan, 1989), (d) be more stable and less impulsive (Merbaum and Hefez, 1976), and (e) be social isolates, prefer to work alone (maintain psychological and social distance), prefer to work with things, not people, and be less susceptible to conformity and conventional responses (Cooper, 1982; Hogan & Hogan, 1989). While successful performers under stress generally appear to have lower self-reported anxiety, fear, and arousal, when they do report increases in anxiety and arousal, it is clearly related to a critical event in the stressful situation (Epstein & Fenz, 1965; Knapp et al., 1976; Ursin et al., 1978; Schedlowski & Tewes, 1992). In addition, there is some evidence (Keinan, 1986) that those individuals more likely to exhibit successful performance may benefit from a more realistic, higher-fidelity, and more potentially dangerous training regimens.

Regarding the question of whether there is a distinctive pattern of psychophysiological activity associated with those likely to perform successfully in stressful occupations, the literature suggests that such a distinctive pattern may be found in cardiac reactivity during the stressful event. The work of Fenz, Rachman, and others have shown that those individuals who perform successfully under stress exhibit a lower level of HR (and to some extent a reduction in HR variability as well) during stressful events than do less successful individuals. Perhaps, more importantly, cardiac responses vary systematically as a function of the stage of the task and its demands: the cardiac responses of successful performers increase early in preparation for the stressful task and then decrease prior to critical aspects of task performance so that at the beginning of the task, the physiological state of arousal (e.g., HR) is essentially at normal (resting) levels.

A PSYCHOPHYSIOLOGICAL MODEL OF COPING UNDER STRESS

Definitions of Psychophysiology

Psychophysiology has been defined in many ways. One of the earliest definitions of psychophysiology noted by Ax (1964) is that "psychophysiology is best defined by its goals and methods as they are described in the reports published by its researchers" (p. 8). Ax (1964) has also provided a more refined definition that "psychophysiology is the description of the systems in the organism which transfer information ... between the psyche and the soma" (p. 10). Similar definitions have been echoed by others as well. Sternbach (1966) defined psychophysiology as "the study of the interrelationships between physiological and psychological aspects of behavior" (p. 3) followed by a listing of the typical methods employed in psychophysiology. Stern (1964) echoed a similar view.

More recently, Furedy (1983) has described psychophysiology as the inquiry concerned with the differentiation of psychological processes by means of unobtrusive, and hence, minimally invasive, physiological measures. This definition places greater emphasis on the psychological aspects of psychophysiology. Perhaps the most recent definition of psychophysiology can be found in the series *Advances in Psychophysiology* (1991) where Jennings, Ackles, and Coles have defined psychophysiology as the scientific discipline concerned with the "theoretical and empirical relationships among bodily processes and psychological factors" (p. ix). This most recent definition is little changed from Ax's earliest definition which defined psychophysiology as the interaction between the psychological and physiological manifestations of behavior.

A Psychophysiological Model of Coping Under Stress

The purpose of the psychophysiological model to be described is to integrate the psychological characteristics of more successful and/or more experienced individuals with the physiological correlates of successful performance under stress. Such a model could be

viewed as a theoretical psychophysiological profile of an individual who copes well with the environmental or task demands under stress. To date, the most reasonable interpretation of the existing data is that successful individuals employ coping processes that lead them to assess an adverse situation differently (Schedlowski & Tewes, 1992; Ursin et al., 1978), a view consistent with the interactional approach to stress. However, this interpretation does not incorporate psychophysiological results nor does it posit an explanation for successful coping. The psychophysiological model proposed here will address these latter issues.

As noted earlier, psychologically the more successfully-coping individual is introverted, self-confident, shows lower anxiety and fear, is more thrill and adventure seeking, has a more internal locus of control, is less social and less susceptible to conformity pressure, and prefers to work with things or on tasks rather than with other people. Generally, the successful coper is internally focused, task-oriented, and less sensitive/responsive to environmental (even social) stressors. These characteristics appear to facilitate a cognitive restructuring of the environment which interprets an adverse environment as being less stressful. Physiologically, the successful coper anticipates the stressful event or task, as indexed by increased arousal (e.g., higher HR or increased skin conductance) prior to the task, and then appropriately appraises the environment such that the task requirements are within his/her resource potential. As one successfully engages in the critical and more demanding aspects of the task, there is a reduction in the level of arousal (lower HR) until indices of arousal are near baseline (resting) levels. In fact, this lower HR may be below normal resting levels. For example, in the case of experienced parachutists, at the actual point of the jump, experienced parachutists showed a reduction in HR (Fenz & Jones, 1972a). (This pattern is more clear in the drop in respiration rate in the Schedlowski and Tewes (1992) study.) One further point is noteworthy. In some studies (e.g., Epstein & Fenz, 1965), the more successful performers showed an increase in anxiety following completion of the critical tasks likely indicating a return to normal levels.

This interpretation of the literature suggests a psychophysiological profile for individuals likely to perform successfully under stress. The successful coper is one who is internally-focused, task-oriented, and less susceptible to external stress-inducing stimuli under conditions where task performance is the primary means of controlling the threatening or stressful situation. This does not mean that the individual is unaware of the potential danger of the task or situation. Rather, it has been shown that the individual will successfully anticipate the situation, and cope with the situation by engaging in productive task activity with maximal physiological efficiency.

To explain the lower arousal (at least lower HR) of successful copers during task engagement, two possible explanations can be offered. The first explanation is that the successful coper interprets the potentially dangerous and threatening situation as relatively neutral, and not anxiety- or fear-provoking, and hence has arousal levels essentially at expected baseline levels. This explanation has several problems. First, this explanation has little face validity given that some degree of threat exists. Second, this explanation cannot explain the anticipatory arousal well in advance of task engagement. Third, this explanation cannot explain the increase in arousal following task completion. Finally, this explanation would have difficulty explaining such results as the HR and RR suppression at the time of the jump for experienced parachutists.

A more plausible explanation for these results is that when individuals are faced with potential threatening or dangerous environments where optimal performance is required, a subset of individuals engage a task-oriented coping process which **actively suppresses or inhibits** exogenous and endogenous stimuli, as well as the consequent arousal normally associated with those stimuli. Thus, rather than viewing a lower HR, or normal HR levels, for decorated bomb disposal operators or experienced parachutists as reflecting less anxiety, or no anxiety, this model views a lower HR level as an active inhibition of the HR increases that are present in non-decorated bomb disposal operators or novice parachutists. Further, this inhibitory control over excessive arousal associated with non-task relevant activity is assumed

to be related to superior task performance. Finally, this model defines successful coping as the active engagement of task-relevant behavior that reduces the disruptive effects of other endogenous or exogenous stimuli. In fact, it can be argued that since task performance will largely reflect a dynamic relationship between environmental demands and the individual's response to those demands, such tasks can be largely viewed as "environmental-intake" tasks (cf. Lacey & Lacey, 1974) involving the reception of critical (or imperative) stimuli from the environment. In this regard, Lacey and Lacey (1977, 1978, 1980) have provided strong evidence that the anticipation of predictable imperative stimuli will lead to cardiac deceleration. In addition, Lacey and Lacey (1974) have argued that a lower HR level will, through decreases in afferent baroreceptor feedback, result in a state of relative cortical excitation and facilitate the reception of critical environmental stimuli and cognitive processing. Thus, individuals with lower HR levels could be at a relative advantage to engage in task-relevant activity.

This psychophysiological model can explain the results in the literature. First, this model has face validity because it assumes that the individual is in fact coping with the existing stressful situation. Second, this model accounts for the anticipatory arousal well in advance task engagement in the stressful environment. Third, this model explains the increase in arousal following task completion as a normal release of inhibition in response to a "safe" environment. Finally, this model would predict that as critical predictable events are approached, as in the case of the jump for the parachutists, a greater focus on the task would elicit greater inhibition of irrelevant arousal which would explain HR and/or RR suppression at the time of the jump for experienced parachutists.

This psychophysiological model of coping has several important implications. First, those individuals most likely to be successful in stressful occupations will show better task-oriented activity and lower levels of arousal. In other words, their physiological efficiency during task performance should be optimal. The degree of arousal associated with task performance should be similar under normal and stress conditions. Second, when engaging in

well-learned behaviors, individuals with smaller physiological reactivity to stressful stimuli should be more resistant to the effects of expected stress. Furthermore, it would be expected that those individuals who show little response to stressful stimuli during task performance would be more resistant to stress effects when the intensity of the stressor is increased. In addition, it would be expected that as performance becomes impaired with increasing levels of stress, the performance reduction would be related to increasing levels of arousal. Psychophysiological measures would be helpful in predicting performance impairment because they would quantify the distraction of the individual from the task-oriented activity due to endogenous or exogenous stressors. Third, individuals with specific personality characteristics, as noted earlier, should typically display lower arousal during task-oriented activity under stress.

The final implication of this psychophysiological model of successful coping under stress is that the physiological mechanism underlying this lower arousal during stress should involve an active inhibition of "fight or flight" types of arousal. For instance, stress is normally assumed to cause "fight or flight" reflexes designed to energize the individual to accommodate the confrontation with the stressor. In physiological terms, stress elicits heightened arousal through an increase in sympathetic nervous system activity, and/or other changes along the pituitary-adrenal axis, which lead to increases in such autonomic indicators as heart rate, blood pressure, skin conductance, and respiration rate. This psychophysiological model assumes that the individual is aware of the stressor, but is actively suppressing or inhibiting the expected stress responses by focusing on the task. This model also assumes that those individuals who are more capable of inhibiting physiological responses to stress should perform better.

If inhibitory control of arousal is critical to controlling the effects of stress, previous studies can only provide indirect support for this hypothesis as these studies have only attempted to measure excitatory responses to stressors. While it may be the case that the lack of an excitatory response may be the product of inhibitory control, this conclusion is in no

way certain. Direct support can only be obtained by the measurement of excitatory and inhibitory control processes. Such measures would be derived from cardiac measures that have been shown to have some sensitivity for differentiating successful from less successful copers under stress conditions.

Criteria for the Utility of Psychophysiological Measures

When attempting to establish the reliability and validity of potentially useful psychophysiological measures that could be used as selection/classification tools to identify individuals for stressful occupations, what are the criteria on which to select some measures over others for more rigorous investigation? This section describes the criteria that were used to choose among the potential psychophysiological measures. These criteria are intended to be independent of the reviewed literature so that some psychophysiological measures are not prematurely excluded because they have not been previously investigated.

The first and most important criterion is that the measures should be able to differentiate the psychological process of interest such as individual differences in reactivity to stress. Many potential measures (e.g., information processing measures) do not meet this *criterion because they are not known to be sensitive to stress.*

Second, potentially useful psychophysiological measures should receive some empirical support from the literature or be logically derived from the existing literature. The scant literature on the topic severely limits the potentially available measures to only a few; in fact, the most commonly reported measure is simple heart rate.

Third, potentially useful psychophysiological measures should be applicable in a practical selection/classification setting. To be useful in a practical setting, candidate measures must be easily acquired, automatically or near-automatically scored, require minimum expertise for interpretation, and be readily available to selection/classification experts. These requirements would tend to eliminate more complex psychophysiological measures from

consideration, especially those that require medical/laboratory expertise to acquire and analyze, such as biochemical and immunologic measures.

Fourth, as previously noted, the best theoretical formulation of successful coping under stress is an interactional or cognitive-relational approach which defines stress as a dynamic relationship between the individual and the environment. Therefore, to be potentially useful, psychophysiological measures should be capable of responding to the dynamic relationship between the individual and the environment. Thus, measures that can be viewed as essentially continuous and minimally obtrusive (so as not to be a source of additional stress) would be preferred to monitor this dynamic relationship.

Fifth, since emotional responding seems to underlie the nature of stress and coping, potentially useful psychophysiological measures should be particularly sensitive to emotionally-laden situations and, as such, should reflect autonomic nervous system changes sensitively. Central nervous system measures such as an electroencephalogram (EEG), which do not clearly differentiate different emotional states, or evoked potentials (e.g., P300), which are particularly sensitive to information processing characteristics, are not likely to physiologically differentiate successful coping though they may be useful adjunct measures in experimental studies (cf. Lukas & Siegel, 1976).

Given these various selection criteria for psychophysiological measures, potential measures would differentiate individual differences in terms of stress, would have received some support in the relevant literature, would be easy to measure and interpret, would be continuous and dynamic, and would reflect autonomic activity. Specific potential measures would include such traditional measures as heart rate, blood pressure, respiration, and electrodermal (skin conductance) activity. However, if one is considering using these measures in a more rigorous practical setting or during a field test (parachuting or bomb disposal simulations) then methodological considerations may restrict the use of blood pressure, electrodermal, and perhaps respiration measures. On the other hand, cardiac measures, such as heart rate, are methodologically easy to acquire and analyze and may be the

most appropriate measures to assess coping responses during stressful conditions (cf., Heslegrave, 1991).

Proposed Psychophysiological Measures

Based on the criteria presented above (e.g., ease of recording and interpretation, applicability to selection/classification environments, and support from the relevant literature), it is proposed that cardiac measures satisfied these criteria and should be investigated more rigorously. However, cardiac measures previously employed have been restricted to heart rate and, to a lesser extent, heart rate variability. To test the psychophysiological model of coping presented in the preceding section, cardiac measures which monitor inhibitory control over arousal are needed. This further criterion suggests that measures more sensitive to inhibitory processes could be potentially more valid than simple measures such as heart rate (HR).

To fully understand the proposed measures, a brief discussion of the regulatory control of HR is necessary. While HR is a measure sensitive to many manipulations, HR does not reflect a single, or for that matter simple, underlying physiological process. In terms of neural control, HR is a mixed measure in that it is dually innervated from both the sympathetic and parasympathetic branches of the autonomic nervous system and is also responsive to homeometric control based on the regulatory demands and feedback loops of the cardiovascular system. Thus, metabolic demands and regulatory control demands (such as through baroreceptor feedback) can overshadow psychological effects and reduce the sensitivity of this measure. In addition, for any measure to be sensitive to inhibitory arousal, it must have two characteristics. First, the measure must be able to respond to inhibitory arousal, and second, the measure must be sensitive primarily to inhibitory arousal. In the case of HR, the first characteristic is true. HR is sensitive to inhibitory arousal because increases in parasympathetic activity lead to bradycardia or a lowering of HR. In fact, the dynamic control of HR is predominately governed by the parasympathetic nervous system when HR is within a

normal range (e.g., 60-100 bpm). Levy (1977) has provided a very good description of the dynamic control of HR by the sympathetic and parasympathetic nervous systems. Thus, with respect to the lower HR of experienced parachutists and bomb disposal operators, it is likely that the lower HR was a function of greater parasympathetic activity. However, HR does not only reflect parasympathetic activity but, as stated above, is sensitive to sympathetic activity as well. Thus, it does not satisfy the second requirement of a psychophysiological measure that is primarily sensitive to inhibitory arousal.

Since stress is known to elicit primarily sympathetic activity, it is important to differentiate sympathetic and parasympathetic influences on HR. In addition, since it is hypothesized that those individuals with greater inhibitory control will perform better under stress, it is important to examine inhibitory processes more directly than by using HR alone. To accomplish this goal, several other measures, such as HR variability measures, that can be derived from a continuous electrocardiogram are proposed.

To date, HR variability has received only *preliminary consideration in the literature*, but there is every indication that successful performers under stress show reduced HR variability (Rachman, 1991). However, HR variability has been defined in terms of standard deviations over variable length epochs. More sophisticated analyses of HR variability are available and these measures may prove to be more sensitive. Specifically, HR variability can be analyzed into its constituent parts which are differentially sensitive to specific physiological processes. Using spectral analysis, most of the variance in HR variability can be accounted for by three bandwidths. The first of these bandwidths is generally considered a high-frequency bandwidth between 0.2-0.4 Hz which is associated with spontaneous respiration and is labeled respiratory sinus arrhythmia (RSA). This high-frequency component has been shown to be a product of the brainstem modulation of parasympathetic efferent tone (Katona & Jih, 1975). Two slower frequency components have also been identified. The first slow frequency component is the Traube-Hering-Mayer (THM) wave between 0.08 and 0.10 Hz and is a product of baroreceptor modulation of arterial blood pressure (Penaz, 1973, 1976, 1978). By

reflecting baroreceptor activity, the THM frequency can be viewed as an index of sympathetic nervous system activity. The second slow frequency component has a peak frequency around 0.01 Hz and is thought to be a product of oscillatory thermoregulatory control (Kitney, 1980).

While none of these components of HR variability are completely free of other influences, they provide more sensitive indices of the mechanisms responsible for HR variability. More importantly, changes in the RSA component of HR variability will provide a relatively more sensitive index of changing parasympathetic inhibition of the heart. It is precisely this type of measure that is needed to assess the psychophysiological model of dynamic task-oriented coping described in the previous section. In addition, both the RSA and THM measures of HR variability have been shown to be sensitive to attentional processes and increased stress (cf. Hatch, Klatt, Porges, Schroeder-Jahseway, & Supik, 1986; Mulder & Mulder, 1981; Porter, Porges, & Marshall, 1988) as well as to the stress induced by fatigue and sleep loss (Heslegrave, 1988, 1987a, 1987b; Heslegrave, Angus, & Pigeau, 1987; Heslegrave, Pigeau & Angus, 1987).

Even if parasympathetic inhibition can be measured with improved accuracy to validate the proposed psychophysiological model, measures of sympathetic nervous system changes should also be considered because they will be necessary to substantiate that different individuals have greater inhibitory control over sympathetic arousal than others. While the slower baroreceptor-mediated component of HR variability may provide an improved measure of sympathetic tone, it too is influenced by other processes, though not to the same extent as HR. However, a continuous recording of an ECG would allow another index of dynamic sympathetic tone to be considered. Specifically, it has been previously argued (Furedy, Heslegrave, & Scher, 1984; Furedy & Heslegrave, 1983; Heslegrave & Furedy, 1983; Heslegrave, Furedy, & Matyas, 1982) that the T-wave component of the ECG provides an electrophysiological index of changes in ventricular function that are modulated by sympathetic nervous system activity. More specifically, as sympathetic activity increases, there is a reduction in the amplitude of the T-wave due to changes in the electrophysiological

characteristics of the heart. In addition, T-wave amplitude has been shown to be a sensitive index of information processing activity and stress reactivity (Heslegrave, & Furedy, 1979; Scher, Furedy, & Heslegrave, 1984), as well as a measure that can differentiate individuals who are differentially sensitive to environmental and occupational stress (Scher, Furedy, & Heslegrave, 1985), such as Type A and Type B individuals (Scher, Hartman, Furedy, & Heslegrave, 1986). Thus, T-wave amplitude could be used along with HR variability measures of sympathetic (Traube-Hering-Mayer wave) and parasympathetic (RSA) tone to more accurately track the dynamic interaction of coping processes for individuals who differentially cope with stress.

Summary and Conclusions

In summary, cardiac measures appear to be potentially useful psychophysiological measures for the selection and classification of individuals for occupations where stress will be present. This conclusion is based on a number of factors outlined in the preceding sections. First, the literature has attempted to distinguish between individuals who perform well in high stress occupations or activities. That literature provides some empirical support for HR and HR variability measures as being sensitive discriminators (and perhaps predictors). While these data are not unequivocal, they do at least support the assertion that HR and HR variability measures may provide an additional benefit beyond standard psychological tests.

To be more specific, the literature suggested that those individuals who cope well under stress appeared to show lower levels of HR (and lower HR variability) than those who were less successful. However, since these results had not been integrated in a psychophysiological model of coping in the literature, a psychophysiological model of coping was proposed based on these findings. The model proposes that those individuals who cope better with stress show anticipatory arousal prior to the predictable occurrence of stress, but *during stress they engage in task-relevant activities in an efficient manner and show only marginal increases in arousal*. The model asserts that successful copers do not ignore the

stressors in the environment, but rather actively suppress or inhibit responses to non-task related stressors. Hence, any psychophysiological measure should be able to monitor this inhibitory arousal in order to accurately and dynamically measure successful coping. HR and HR variability measures would allow monitoring of both excitatory and inhibitory processes.

Second, cardiac measures are amenable to sophisticated analyses of excitatory and inhibitory processes. Specifically, refinements include more detailed monitoring of HR; more sophisticated analysis of HR variability to differentiate oscillatory processes that reflect changes in sympathetic (excitatory) and parasympathetic (inhibitory) nervous system activity; and, an analysis of electrocardiographic characteristics (T-wave amplitude) which have been shown to be sensitive to information processing load and stress.

Third, the proposed cardiac measures satisfy the criteria necessary for potentially useful psychophysiological measures for selection/classification purposes. Namely, cardiac measures are easily acquired, automatically or near-automatically scored, require minimum expertise for interpretation, are unobtrusive, and can be readily available to selection/classification experts. In addition, these measures are continuous so they have the potential to track the dynamic relationship between the individual and the environment.

At this point it is necessary to clearly highlight two caveats with respect to the recommended choice of potentially useful psychophysiological measures to be initially investigated. First, while the cardiac measures noted above satisfy the criteria proposed in this report and show promise with respect to their utility, it cannot be overemphasized that construct and predictive validation of these measures has yet to occur. The data from the literature are suggestive but not conclusive. In addition, while the psychophysiological model presented in this report attempts to explain and generalize from the known results, there has been no empirical test and validation of this model. Therefore, even though the proposed measures and the model show promise, their validity must be empirically verified.

Second, even though the literature supports the further assessment of these proposed psychophysiological measures, other potentially useful psychophysiological measures should

not be entirely excluded. Indeed, if the model leads to a clearer understanding of the differences between individuals in terms of successful coping under stress, it may still be the case that more basic laboratory or clinical measures may be uncovered that differentiate types of individuals. It is clear that more basic biological mechanisms could underlie characteristic cardiovascular responses to stress.

In this regard, it may be that the cardiovascular indices of inhibitory control reflect a predisposition toward inhibitory control at the neurophysiological level. Some (such as Gray (1976a, 1976b) and Fowles (1980)) have suggested that there are fundamental differences in the adrenergic and noradrenergic pathways in the limbic system that support predispositions toward a dominance in excitatory or inhibitory arousal. Fowles (1980) has postulated that individual differences in these pathways may be predictive of different psychopathologies. He has suggested that if individual differences in inhibitory control account for a significant portion of the variation in psychopathologies, then inhibitory control may reflect a basic fundamental neurophysiological difference between individuals. As an analogy, one might consider schizophrenia. For many years, schizophrenia was primarily thought of as consisting of bizarre behaviors and thoughts. While subsequent research in no way altered this description as part of the clinical description of schizophrenia, this research demonstrated that some schizophrenics could be significantly helped by neuroleptics which focused on abnormalities in the dopaminergic system. Thus, for at least some individuals, a neurophysiological substrate of schizophrenia (regarding dopamine receptors) was identified. It may be that physiological differences between those individuals more and less capable of performing under stress may lead, eventually, to an understanding of some neurophysiological substrate of successful coping under stress. Nevertheless, it is clear that examining psychophysiological differences between individuals is a step toward such improved understanding. Without research in the area of psychophysiological responses associated with successful coping, it is doubtful whether significant improvements in our understanding can be achieved. Even if such research fails to demonstrate consistent physiological differences

between individuals, such work will nevertheless advance our understanding of the psychological processes involved.

Furthermore, if a physiological or neurophysiological substrate or correlate of successful coping exists, it may not be sufficient to predict one's performance under stress. Just as with schizophrenia, the neurophysiological or genetic predisposition toward schizophrenia are not sufficient to predict the occurrence of schizophrenic symptoms in individuals. The occurrence of schizophrenic symptoms in individuals appears to be caused by the unsuccessful coping of individuals predisposed to schizophrenia when faced with environmental stress. Likewise, the successful coping of individuals in response to exogenous and endogenous stressors can only be assessed adequately in the presence of those stressors and with a thorough understanding of all characteristics of the environment. Thus, for a pattern of physiological responding under stress to be a valid index of successful coping in stressful occupations, the nature of the dynamic relationship between the stressors and the individual's interpretation of those stressors must be clearly understood. A clear understanding of the impact of potential stressors in occupations of interest is therefore essential.

CURRENT INDUSTRIAL/ORGANIZATIONAL APPROACHES TO OCCUPATIONAL STRESS

This section contains a brief evaluation of previous studies that have examined predictors of stressful military performance. The evaluation is discussed with the context of Industrial/Organizational Psychology (I/O Psychology). Additionally, a review of current I/O approaches to analyzing occupational stress is presented. This review will provide a context for the later discussion on the proposed research into identifying stress in occupations.

I/O Psychology Evaluation of the Cited Literature

Although important information has been collected regarding the attributes of successful performers, the predictors and criteria used in previous studies of predicting stressful military performance are questionable. Traditional I/O Psychology approaches to selection, such as job analytic and validation procedures were not used in these studies. For example, it is difficult to evaluate the validity of the predictors and criteria measured in these studies since job analyses were not conducted. Additionally, with the exception of Hogan and Hogan (1989), the criteria used in the studies were not validated. Even Hogan and Hogan (1989) used only the concurrent method to validate their criteria and did not evaluate its construct and predictive validity. The predictors and criteria varied from study to study and the rationale for measuring particular variables within a given study was absent.

A further problem with previous studies is that, with the exception of Rachman (1991), Keinan (1989), and Hogan and Hogan (1989), researchers have not used performance as their criterion. Instead, various measures of physiological, emotional, and/or cognitive responding have been used as the criteria. Even when performance was measured as the criterion, psychophysiological indices were not always used as predictors (cf., Hogan & Hogan, 1989; Keinan, 1989). Thus, it is difficult to consolidate findings across studies, and consequently, the relationship between psychophysiological responses to stress and performance in this context is still vague. Given these problems with previous studies, it is important to review current I/O approaches to analyzing occupational stress in order to apply these approaches to the selection of personnel for stressful occupations in the military context.

Job Analytic Procedures

Landy (1988) has suggested that the critical component of any selection procedure is to identify the tasks, knowledge, skills, and abilities required to perform a job. Further, Landy (1988) has noted that job analytic methods are used to provide guidelines for deciding which behaviors to predict in selection testing. Specifically, Landy (1988) has suggested that job

analysis information can be used to identify the knowledge, skills, abilities, and other factors (KSAOs) that are useful for accomplishing the job tasks. The goals of this open-systems approach to job analysis are: (a) the identification of job-relevant behaviors, (b) the identification of KSAOs required to perform these behaviors, and (c) the identification of valid measures of the KSAOs or valid indicators of the presence of the necessary KSAOs. The KSAOs represent the output of the job analysis.

Although numerous approaches for analyzing jobs in terms of their tasks, knowledge, skills, and abilities have been developed, their application to stressful jobs has been somewhat limited. Nevertheless, Fleishman and Quaintance (1984), Siegel (1988), and Solomon (1986) have examined various jobs in terms of their stressful components, as well as the KSAOs required for performing them. Their efforts suggest that the classification of stressful jobs in terms of stress-inducing tasks and KSAs has the potential to enhance our understanding of human performance in stressful situations. These three approaches are reviewed next.

Fleishman's Taxonomy of Human Abilities

The use of KSAOs for prediction purposes is relatively straightforward, especially with the development of various taxonomies of human abilities. For example, Landy (1988) has suggested that the Fleishman and Quaintance (1984) taxonomy of human abilities is particularly well-suited for job analysis activities since it offers a complete description of the cognitive, perceptual-motor, and motor abilities that are required for performing most jobs. Furthermore, their taxonomy is particularly noteworthy since it has been used to examine stressful components of jobs.

Fleishman and Quaintance (1984) have defined stress according to the psychomotor abilities required for task performance. For instance, they examined the effects of different noise stressors on reaction time, rate control (i.e., tracking), and time-sharing tasks in order to quantify the effects of stress. Overall, they found that random, intermittent, moderate-intensity noise (85 db) was more likely to affect some aspects of task performance than others. Thus,

tasks that differed in terms of the ratio of reaction time, rate control, and time-sharing components would be differentially affected by intermittent noise. Specifically, they found: (a) significant detrimental effects of random intermittent noise upon reaction time, (b) an absence of significant effects of random intermittent noise upon rate control, and (c) an initial absence of significant effects of random intermittent noise upon time-sharing tasks, but significant detrimental effects after continued exposure. Fleishman and Quaintance (1984) suggested that these results illustrate differential effects of stress upon various aspects of performance.

Siegel's Human Factors Approach

Siegel (1988) has also examined various jobs in terms of their stressful components. He has reviewed several approaches to identify and quantify the presence of occupational stress. These approaches to measuring stress in the workplace have included: (a) the direct assessment of job dimensions using the Position Analysis Questionnaire (PAQ), (b) using workload measures to assess stress, and (c) using decrements in abilities to measure stress.

To illustrate the utility of the PAQ, Siegel (1988) reviewed Shaw and Riskind's (1983) study which investigated the relationship between PAQ job dimensions and various indices of job stress. Siegel reported that there were statistically significant negative correlations between processing information and heart problems (-.32) and hypertension (-.26), but performing controlled manual activities and being in hazardous job situations were positively correlated with heart problems (.35 and .33, respectively) and hypertension (.29 and .24, respectively).

Workload as a measure of job stress has also been reviewed by Siegel (1988). The tasks performed by U.S. Army helicopter crews during various phases of flight were identified, and then evaluated in terms of the various intellectual and the psychomotor loads placed upon each crew member. The ratings (using a 7-point scale) of the intellectual and psychomotor loads were used to identify the intellectual and psychomotor categories that produced the greatest amount of mental load/stress. For example, for the task of

reading/monitoring flight, caution, and warning instruments, the intellectual categories of cognition of symbolic units, evaluation of symbolic classes, and evaluation of symbolic relations produced the greatest mental load/stress. For other tasks, however, different intellectual categories were related to mental load/stress. For example, when using the navigation system to fly a course, memory of symbolic units, cognition of symbolic relations, and memory of semantic units produced the greatest mental load/stress.

The final approach reviewed by Siegel (1988) is the ability decrement approach. Subject matter experts (SMEs) rated the effects of stress upon the performance of each task in a comprehensive list of the tasks performed by mechanized infantry teams. Prolonged battle stress was considered to affect communication, memory, perceptual speed, and reasoning abilities. Each task was rated on whether or not it required these abilities for successful performance, and these data were used to calculate the expected degradation in performance effectiveness after 24 hours of continuous activity. Siegel (1988) has suggested that the differences in ability decrements among crew members primarily reflect differences in ability requirements for different positions. In addition, since cognitively related abilities are affected by stress to a greater extent than motor abilities, they noted that the performance of the squad leader, the person with the most cognitively-demanding tasks, is projected to degrade the most.

Solomon's Job Characteristics Model

Solomon (1986) developed a model of task functions that examines the motivating and stressful properties of jobs. She has noted that the motivating aspects of a job interact with the stressful aspects in creating individual responses to stress. In doing so, Solomon (1986) integrated the motivating properties (autonomy, skill variety, task significance, task identity, and feedback) with the stressful ones (role ambiguity, role conflict, role overload, and role-status congruency) in her definition of job properties.

In Solomon's study, 240 executives responded to a 20-item questionnaire that contained items defining (a) opportunities to exercise independence and responsibility, (b) opportunities to experience challenge and significance, and (c) clarity and specificity of their role. These executives rated each item in terms of its presence in their jobs, its importance, and their satisfaction with this aspect of their jobs. Solomon (1986) used facet analysis to identify the dimensions underlying the 20 items, and she has found systematic and consistent relationships (i.e., correlations ranged from .39 to .88) between the items for each of the existence, importance, and satisfaction ratings. The underlying job properties that have emerged include facilitative structure, autonomy for action, clarity of structure, and autonomy for need fulfillment. Overall, these results suggest that it is possible to differentiate jobs in terms of their stressful properties.

Summary

The preceding review suggests that a systematic analysis of stressful jobs would enhance our understanding of the KSAOs required to perform them. Various dimensions of stress have been examined and consistent relationships between stress and KSAOs have emerged. Fleishman and Quaintance (1984) have shown that an environmental stress dimension (i.e., noise) stressor differentially affected various types of psychomotor abilities so that performance decrements occurred on some job tasks (i.e., reaction time and time-sharing), but not on others (i.e., rate-control). Furthermore, Siegel (1988) reviewed several approaches to collecting stress information and has identified systematic patterns of the stress response as a function of task characteristics, workload, and fatigue (battle stress) dimension of stress. For each stress dimension, Siegel (1988) identified its negative effect upon various cognitive abilities. Solomon (1986) integrated motivating and stressful job properties to include stress within the job analysis. She found that a facilitative and clear structure, autonomy for action, and autonomy with respect to need fulfillment were the task dimensions

underlying various indices of the job properties. Although Solomon (1986) identified various stress dimensions, she did not examine their relationships with KSAOs.

Stress Dimensions and KSAOs

It is noteworthy to mention several issues regarding these studies. First, although they investigated the effects of stress on various KSAOs, none of these studies included measures other than cognitive abilities. The "O" (other factors) component of this taxonomy may provide more predictive information than cognitive abilities, especially when the criterion is performance on a stressful job. For example, the "O" component could include psychophysiological responses (e.g., heart rate and heart rate variability) to a stressful stimulus.

Another limiting factor of these studies is their operationalization of stressful stimuli. In the studies that were reviewed, stress has been operationalized as noise (e.g., Fleishman and Quaintance, 1984), PAQ dimensions, ratings of the intellectual and psychomotor loads placed upon individuals, ratings of the effects of prolonged battle stress (Siegel, 1988), and role conflict/role ambiguity (Solomon, 1986). It is likely that a systematic classification of job stressors will enhance our understanding of the KSAOs required for effective performance in stressful situations.

A job analysis of demanding tasks would identify their stressful dimensions, as well as the knowledge, skills, abilities, and other factors (KSAOs) required to cope with the stressors. Specifically, job analytic procedures would identify dimensions of the job stressors that could be used to provide a rationale for the selection of valid KSAOs and to develop predictors of performance in stressful jobs. Manipulations of stress conducted in the laboratory, field, and survey studies could provide the basis for the development of these dimensions. Table 1 shows some potential dimensions of stress, examples of their manipulation, and the authors of the studies.

Table 1.
Dimensions of Job Stress

Stress Dimensions	Manipulations	Authors
Uncertainty	Intermittent parachute malfunction	Fenz & Jones (1972b)
Ambiguity	Clarity of structure	Solomon (1988)
Conflict	Multiple psychomotor tasks	Cox et al. (1983)
Control	Move a lever in the direction of the tone	Rachman (1989)
Workload	Intellective and psychomotor load	Siegel (1988)
Environmental Stressors	Noise	Fleishman & Quaintance (1984)
Threat	Electrical shock	Rachman (1989)

A job analytic approach to stressful occupations could have job incumbents provide behavioral examples of the job stress dimensions in Table 1 (uncertainty, ambiguity, conflict, control, workload, environmental stressors, and threat), and their frequency, importance, and intensity would be rated to determine the most significant stressful job properties. In addition to these subjective ratings, the effects of these dimensions upon various KSAOs could be examined. A study similar to the one described by Fleishman and Quaintance (1984) could be designed to examine the effects of these dimensions upon performance of tasks requiring specific KSAOs (e.g., cognitive abilities and psychophysiological coping). On the other hand, studies could also be designed which examine how specific KSAOs (such as HR variability responses to stress) moderate the impact of these dimensions on performance.

The differential effects of these dimensions have important implications for the identification of KSAOs as well as for the development of predictors. For example, Sosnowski (1983) demonstrated the differential effects of uncertainty, threat and ambiguity on responses to stress in a laboratory experiment. He found that threat and ambiguity had greater effects on heart rate and skin resistance than did uncertainty. Sosnowski's (1983) findings suggest that job-relevant stressors should be manipulated in order to validate predictors of successful performance in stressful jobs. It is possible, for example, that the reason Rachman (1989) failed to find strong empirical support for psychophysiological predictors was a result of manipulating a noncritical dimension of stress. Furthermore, Rachman (1989) did not present any evidence to indicate that his threat manipulation was more powerful than manipulating stress dimensions (e.g., ambiguity or conflict). A comprehensive, dimensionalized analysis of stressful jobs would provide the basis for resolving many of the issues identified in the review of predicting stressful military performance.

FUTURE DIRECTIONS FOR THE SELECTION OF PERSONNEL FOR STRESSFUL OCCUPATIONS: THREE PARALLEL APPROACHES

The preceding sections of this report focused on the potential utility of psychophysiological measures for selecting personnel who would be successful in stressful occupations. The report began by identifying the rationale for the need to better select personnel for such occupations. This was followed by a review of the effects of stress on performance and an examination of the theoretical underpinnings associated with stress and coping. A review of the relevant literature on stressful occupations and selection procedures followed with special emphasis on those occupations relevant to the military, and especially those tasks or occupations that have in the past used psychophysiological measures to differentiate successful from less successful individuals in stressful situations. While this

literature provides some useful information, integration was needed. Consequently, a new psychophysiological model was developed to provide a more plausible theoretical explanation of the findings. Finally, all of this information was framed within the context of current industrial/organization practice.

Based on the review of the literature and the shortcomings of past and present approaches to selecting personnel for stressful occupations, our conclusion is that psychophysiological measures may provide useful tools for the selection/classification of personnel for stressful occupations and for performance under stress in all occupations. However, research specifically focusing on this issue is necessary before such a conclusion can be made with certainty.

To address the issues raised in this report it is recommended that three parallel approaches to examining the issue of selecting and classifying individuals for stressful occupations be undertaken. First, experimentation is needed to assess the validity of the *proposed psychophysiological model designed to explain individual differences in successful coping under stress*. Second, since it was suggested that individuals who are more successful at coping under stress appear to have a cluster of personality traits that support their coping strategy of focused task engagement, research should be conducted into the personality correlates of successful task performance under stress. *If stable personality variables can be found that are correlated with psychophysiological response patterns and a preference to engage in task performance under stress*, then selection and classification of such individuals will be easier and more practical. Third, occupations must be analyzed in terms of their stressful dimensions. This analysis would provide a rationale for the identification of valid predictors and criteria of successful performance across a wide range of stressful jobs.

It should be noted that these three lines of future research are necessarily considered parallel or simultaneous tracks rather than sequential because findings in any of the three areas (psychophysiological assessment, personality correlates, and job analysis) will influence the direction of research in the other areas. For instance, if patterns of psychophysiological

responding appear to differentiate successful copers from less successful copers in a specific stressful occupation, then it may be possible to rank-order the importance of specific stress properties of the tasks within that occupation by examining psychophysiological response patterns. On the other hand, if a job analysis of a stressful occupation reveals a specific property which differentiates successful and unsuccessful copers, then this property should be investigated within the psychophysiological paradigm. Therefore, all three lines of research should be conducted simultaneously and in parallel since findings in any of these lines of research can directly benefit the research in other areas.

I. Psychophysiological Patterns of Successful Coping

The first of these three parallel lines of research should be to investigate the predictive validity of psychophysiological patterns of successful task performance under stress. Initial experiments should be aimed at validating the psychophysiological model proposed in this report. This model conceptualizes successful coping in stressful occupations as the ability (or preference) to focus on task properties and actively suppress or inhibit exogenous (e.g., environmental stressors) or endogenous (e.g., fear) stimuli. This task-engagement strategy is viewed as a coping strategy. Given this coping strategy, it is hypothesized that there will be efficient utilization of physiological resources targeted at task completion and an inhibition of responding to extraneous stimuli. Moreover, these inhibitory processes will manifest themselves as inhibitory arousal. It is hypothesized that heart rate changes in more successful copers will be lower than heart rate changes in less successful copers (due to greater parasympathetic nervous system arousal), but that there will be greater changes in heart rate variability measures since these measures more precisely reflect inhibitory processes. In addition, it would also be expected that there might be increases in measures of sympathetic arousal (such as an attenuation in T-wave amplitude) reflecting that successful copers are sensitive to the environmental characteristics, but are moderating those influences by inhibiting their responses. Finally, it would be expected that as the degree of stress increases, the

appearance of inhibitory processes would become more evident. More importantly, performance on well-learned tasks should be related to this inhibitory control over the influence of extraneous stimuli such that more successful copers should show stronger inhibitory control and better performance.

Initially, experiments to assess this model should be conducted in the laboratory where there is better control over independent (stress-related) and dependent (psychophysiological) variables. These experiments should focus on describing the individuals who demonstrate the best patterns of performance and physiological change associated with increasing levels of stress. Since a wide variety of experiments to assess the validity of this psychophysiological model of successful coping under stress can be conceptualized, specific experiments will not be detailed. In addition, such experiments may be serially dependent on the results of earlier studies. However, if these initial laboratory experiments are successful, then more operational (real or training) settings should be investigated. Since the laboratory is theoretically limited in terms of creating stressful conditions, it is imperative to conduct such experiments under high-fidelity training or operational conditions after gaining a better understanding of the processes involved.

II. Personality Characteristics of Successful Coping

The second of these three parallel areas of research should investigate personality characteristics identified in individuals who have successfully coped with stressful situations. Psychologically these individuals are introverted, self-confident, show lower anxiety and fear, are more thrill and adventure seeking, have a more internal locus of control, are less social and less susceptible to conformity pressure, and prefer to work with things or on tasks rather than with other people. Generally, the successful coper appears to be internally focused, task-oriented, and less sensitive/responsive to environmental (even social) stressors leading that individual to interpret an adverse environment as less stressful.

A series of experiments should be conducted based on these personality variables. Specifically, these studies should select individuals who polarize themselves on a variety of the personality characteristics noted above. In this way, the personality characteristics that appear to be associated with better performance under stress can be more clearly assessed. It may be that only a few variables clearly differentiate those more likely to cope effectively with stressful environments and occupations. While different personality characteristics will be explored in this research, the criterion variable will remain successful performance under stress.

III. Job Analysis of Stressful Military Occupations

The third of these three parallel lines of research should develop a conceptualization of the dimensions of stress inherent in military occupations. Job analytic procedures would be used to assess the stressful properties of specific military occupations. Research in this area would begin with interviews with *job incumbents* and their superiors to generate critical incidents of stressful dimensions of task performance. These items would then be used to develop a survey that would be administered to both job incumbents, their superiors, and training personnel. The respondents would rate the frequency, importance, and intensity of each item. Descriptive statistics would be used to determine the most critical dimensions that contribute to stressful job performance. Two methods would be used to identify the KSAOs that are representative of the critical dimensions. First, subject matter experts (SMEs) would assess the KSAOs required for effective performance, and inter-rater reliabilities would be computed. The second method would be a study similar to the one described by Fleishman and Quaintance (1984) in which the differential effects of the stress dimensions upon the KSAOs would be assessed. The goal of this work would be to differentiate those dimensions of the job that distinguish successful performers under stress from those less successful under stress. Using the most discriminating KSAOs, recruits would be selected on their ability to cope with the most dominant stressors for that occupation, as well as an actual assessment of

their coping abilities under high-fidelity training, assessment simulations, or situational tests. In parallel developments, cognitive, psychophysiological, and personality predictors, as well as performance criteria (e.g., supervisory ratings), would be assessed.

A DEMONSTRATION EXPERIMENT

To focus the preceding discussion, a demonstration experiment is presented. In establishing the rationale for this experiment, it is assumed that laboratory experiments have shown some promise for the utility of psychophysiological variables and that inhibitory processes seem to be important. In addition, it has also been assumed that the job analysis of, for example, Special Forces personnel, has shown that immediate physical threat is a critical stressor under which they must perform without showing any performance impairment. To assess the relationship between psychophysiological responses and performance, the following experiment could be conducted.

Method

Subjects. Three groups of subjects would participate in this study. Experienced personnel (with various levels of successful performance under stress as rated by the supervisor), new recruits, and potential applicants would be sampled. These groups would vary in experience and commitment to the occupation. In addition, the groups would vary along other important dimensions including personality characteristics, skill level, and psychophysiological reactivity.

Experimental Manipulations. Subjects would engage in a stressful task simulation similar to the Trench Test described by Keinan (1988) and would be matched in terms of marksmanship. The Trench Test would be carried out in a fortified 50 meter trench (0.8 meter wide and 1 meter high) in which two 6 meter shooting areas are displaced from a target by 10 meters. The subject would be equipped with two ammunition magazines and his task

would be to crawl along the trench and shoot at a target from each of the two shooting areas. This test would be carried out under two levels of stress. In the high-fidelity condition, subjects would be told that live ammunition would be fired over their heads by their squad leaders while they crawled through the trench. (In the Keinan study, live ammunition was used, but with a wide safety margin.) In addition, a medic would check the subject's blood type before the test is started to enhance the validity of the simulation. In the low-fidelity condition no shots would be fired.

The ASVAB, the Assessment of Background and Life Experiences (ABLE), and the Hogan Personality Inventory would be administered prior to the simulation. During the simulation, an electrocardiogram (ECG) would be continuously recorded so that HR, HR variability (including both the respiratory and blood pressure (baroreceptor) spectral bandwidths), and components of the ECG (e.g., T-wave amplitude) could be assessed. Additionally, supervisory personnel would observe the subjects' performance during the simulation in order to complete performance evaluations. Performance data would be collected at three additional intervals to provide longitudinal data with respect to predictive validity; specifically, data would be collected at six months, one year, and two years after participation in this study. Supervisory ratings and other standard measures would provide the performance data.

Predictors. The predictors used in this study would include the ASVAB, the ABLE, the Hogan Personality Inventory, and psychophysiological measures (i.e., HR, respiratory and baroreceptor spectral bandwidths of HR variability, and T-wave amplitude) continuously recorded using ambulatory physiological methods.

Criteria. The criteria measured in this study would include objective measures of task performance (i.e., number of hits on a target, time to complete the trench test), supervisory ratings of performance during the simulation, and supervisory ratings of the subjects' actual job performance. The information collected in the job analysis research would provide the format for the performance ratings.

Data Analysis. The concurrent and predictive validity of the predictors would be analyzed in this study. The ASVAB, the personality inventory, and the psychophysiological measures would be used to predict the subjects' performance during the experimental task. The moderating effects of the stress dimension(s), test sequence, and experience level would also be assessed. At intervals of six months, one year, and two years upon completion of this task, the predictive accuracy of the ASVAB, the personality inventory, and the psychophysiological measures would be examined.

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